THE SYSTEMATICS OF SOUTH AUSTRALIAN PRECAMBRIAN AND CAMBRIAN STROMATOLITES. PART III

by W. V. PREISS*

Summary

PREISS, W. V. (1974).—The systematics of South Australian Precambrian and Cambrian stromatolites. Part III. *Trans. R. Soc. S. Aust.* **98**(4), 185-208, 30 November, 1974

Three new forms of stromatolites from South Australia (*Linella munyallina, Tungussia etina,* and *T. wilkatanna*) are described. South Australian occurrences of *Omachtenia utschurica* and *Linella ukka,* previously known from the USSR, are also discussed.

Introduction

This paper is a continuation of Parts I & II (Preiss 1972; 1973a), in which the principles of stromatolite classification were outlined and new forms of stromatolites described. The glossary appended to Part I also applies to this paper

Systematics

Group LINELLA Krylov

Linella Krylov 1967: 37.

Type Form: Linella ukka Krylov, from the Uk Suite of the Southern Urals.

Diagnosis: Bumpy, subcylindrical or tuberous, usually walled columns with parallel to markedly divergent branching and numerous, often pointed, projections.

Content: L. ukka Krylov, *L. simica* Krylov, *L. avis* Krylov, *L. munyallina* Preiss, and *L. zhuica* Shenfil' (*in* Khomentovskiy *et al.* 1972).

Age: Apparently only Vendian in the USSR, but in Central Australia *L. avis* occurs in rocks correlated with the Late Riphean (Walter 1972). In South Australia, *Linella* occurs in beds probably approximating to the Late Riphean–Vendian boundary in age.

Linella ukka Krylov 1967: 39.

FIGS. 1a–h, 5a, 6a, 7a–e

Material: Six specimens from Burr Well and Leigh Creek.

Description

Mode of Occurrence: The stromatolites form lenticular beds, not more than 20 m long and 0.5 m thick, consisting of adjoining domed bioherms 2 m in diameter. In the centres of individual bioherms, columns are vertical or variously inclined (Fig. 7a), but at the bioherm margins they become uniformly reclined (Fig. 7b). Margins of adjacent bioherms are poorly defined. At one point, at the edge of a lenticular bed, the columns commence growth vertically, but then curve over and grow horizontally outwards. Biohermal beds grade into laterally linked hemispheroidal and pseudocolumnar stromatolites, which intertongue with the underlying intraclastic limestone. They are overlain by oolitic limestones or grey calcareous shales.

Column Shape and Arrangement: Columns are subcylindrical to tuberous, sometimes slightly flattened in various directions. Transverse sections are round, oval, rounded polygonal or complexly lobate, 1–8 cm in diam. Columns may swell and constrict markedly over a length of a few centimetres. The length of columns between branches is usually less than 5 cm, but individuals reach a height of up to 30 cm (Figs 1a–h). Columns may be variously oriented, from vertical and parallel to inclined at up to 45° to the vertical, but at bioherm margins columns are radially or horizontally arranged.

Branching is frequent and varies in style from β- to γ-parallel, or slightly divergent to markedly divergent. Moderately divergent branching is the most frequent (Figs 7c,d,e). Columns may be constricted at the base of branching (Fig. 1a). Approximately 50% of branching does not result in new complete

* Geological Survey, South Australian Department of Mines, Box 38, Rundle Street P.O., Adelaide, S. Aust. 5000.

columns, but forms narrow, pointed, or sometimes slightly flattened outgrowths 1–4 cm long, generally less than 1 cm in diam. (Figs 1a–h). These pointed outgrowths are also variously oriented, and may project at a high angle from the main column. Coalescing of adjacent columns is moderately frequent.

Margin Structure: Column margins vary mainly from smooth to gently bumpy; occasionally sharper bumps of approximately 1 cm diam. occur. Very short ribs are rarely present. Short overhanging peaks occur in a few places, especially near points of bridging. Bridges, where present, consist of many laminae. A wall up to 3 mm thick is present on the whole lateral surface not affected by peaks and bridges. The number of laminae participating is difficult to estimate, due to secondary recrystallization (Fig. 7d). Columns are sometimes coated with a selvage of fine sparry calcite, of xenotopic equigranular texture and grain size 0.01 mm. The selvage is up to 1.5 mm thick and postdates the formation of the wall, but pre-dates the filling of the interspace.

Lamina shape varies greatly within single columns, from almost flat or rectangular to very steeply convex (Fig. 5a). The majority (79% of laminae measured) have h/d between 0.2 and 0.6 (Fig. 6a). Laminae are very poorly preserved, so that their detailed shape is difficult to estimate. Most are smooth, but some are finely wavy, with a wavelength of 2–3 mm. Single laminae are difficult to follow across a whole column width. The degree of inheritance of lamina shape varies along a column length; in places laminae change rapidly from gently convex or rectangular to steeply convex.

Microstructure is poorly preserved, and the lamination is extremely indistinct. There is little contrast between light and dark laminae, except a slight difference in pigmentation and in grain size (Fig. 7d). *Dark laminae* are smooth to slightly wavy and lenticular, 0.1–0.4 mm thick. Single laminae cannot be traced right across columns, partly because of recrystallization. Upper and lower boundaries are very diffuse and more or less parallel. In most places, laminae are reduced to aligned lenses of fine grained carbonate. Dark laminae consist of hypidiotopic to xenotopic inequigranular calcite, grain size 0.003–0.015 mm. Most crystals are lightly pigmented pale grey (possibly an organic pigment). In one specimen, dark laminae are dolomitized. Subangular quartz silt of grain size 0.02–0.05 mm occurs in places in both dark and light laminae. *Light laminae* are 0.2–0.6 mm thick, and as discontinuous as the dark laminae between them. They consist either of acicular, or equidimensional mosaic calcite. Acicular crystals are 0.01–0.02 mm wide, and are arranged perpendicular to the laminae, and often extend also into the dark adjacent laminae. They are therefore clearly secondary. The equidimensional calcite is xenotopic, grain size 0.02–0.04 mm.

Interspaces between columns are filled mainly with poorly bedded intraclast grainstone. Allochems, including fine pellets of dense, dolomitized micrite, 0.02–0.1 mm in diam., and small, flat, curved or irregular intraclasts up to 0.5 mm long, are packed and mostly in contact. They are cemented by transparent sparry, xenotopic calcite of grain size up to 0.2 mm. A few crude bands of dolomitized micrite, up to 1 cm thick, occur in places. These are extremely dense, fine grained, but contain some pellets and intraclasts.

Secondary Alteration: Stromatolite columns are severely recrystallized, especially near column margins (Fig. 7d). Here laminae are severely disrupted by lenses and irregular patches of recrystallized, xenotopic to hypidiotopic sparry calcite, of grain size up to 0.2 mm. The laminae are reduced to small, irregular or curved, disoriented remnants; in places a secondary grumous texture is developed. In addition there are numerous irregular lenses, up to 4 mm thick, of nearly opaque, white, fine dolomite, aligned parallel to the lamination (Fig. 7e). The dolomite is equigranular, hypidiotopic, grain size 0.01–0.02 mm. Most intraclasts in the interspaces are also dolomitized, or at least surrounded by dolomitic rims, but the sparry cement is unaffected. Straight and irregular calcite veins post-date the dolomitization. Stylolites in places cut across all structures of the rock, but were not seen in thin sections. Nodules of coarsely crystalline calcite similar to those in *Inzeria* cf. *tjomusi* from Burr Well (Preiss 1973a) are locally present.

Comparisons

The stromatolites are identified as *Linella* by their bumpy, subcylindrical and tuberous, parallel to markedly divergent branching, walled columns, and numerous pointed projections. Many specimens of *Baicalia* have similar gross shape, but lack the almost ubiquitous wall and the numerous pointed projections of *Linella*. They are assigned to *Linella ukka* Krylov on the basis of column shape, style of branching, and margin structure. Unlike *L. simica* Krylov, ribs are poorly developed or absent. The columns are more broadly bumpy, more divergently branching, and less gnarled than those of *L. avir* Krylov. Microstructure is less well preserved than in the type material but lamina shape is very similar. *Linella ukka* from Burr Well is very similar in microstructure, margin structure, lamina shape and mode of preservation to *Gymnosolen* cf. *ramsayi* from limestone clasts in the Tapley Hill Fm. but is distinguished by its bumpier, more tuberous, divergently branching columns. Krylov (1967) described *Tungussia bassa* as a separate form, but states that it occurs at the margins of *Linella ukka* bioherms. Similarly, at Burr Well, inclined and horizontal columns occur at bioherm margins, but these are here included in *Linella ukka*. *L. zhuica* Shenfil' rarely has a wall.

Distribution: Uk Suite of the Southern Urals and in beds correlated with the Klyktan Suite of the Central Urals, USSR; Balcanoona Formation, Burr Well and Leigh Creek, Northern Flinders Ranges, S. Aust. *Linella* aff. *L. ukka* (Cloud & Semikhatov 1969) occurs in the Johnnie Formation, South Ibex Hills, California, USA.

Age: Late Adelaidean: in the USSR it is apparently restricted to the Vendian.

Linella munyallina f. nov

FIGS. 1i–y, 2a–n, 5b, 6b, 8a–f, 9a–c

Material: Twenty-six specimens from West Mount Hut, Termination Hill, Lake Arthur, Myrtle Springs, Burr Well, Roebuck Bore and Arkaroola areas.

Holotype: S495 (Figs. 1x,y; 2a–c; 9b), 5 km east of Myrtle Springs.

Name: After Munyallina Valley, where the stromatolites of the Arkaroola area occur.

Diagnosis: *Linella* with dominantly parallel branching, a wall that is discontinuous on some columns, and with highly variable lamina shape. Columns are gently bumpy, and pointed projections are subordinate.

Description

Mode of Occurrence: These stromatolites are widespread in the Wundowie Limestone of the Northern Flinders Ranges, where they occur in domed biostromes and lenticular beds consisting of contiguous domed bioherms, commonly overlain by thin sandy limestones, and/or interbedded in green or red shales. The biostromes vary in thickness in different areas from 50 cm to 2 m, depending on the relief of the individual bioherms they comprise. At Burr Well, individual bioherms are isolated (Figs. 8a,c,d) or contiguous, so that stromatolite beds are lenticular, and recur at different stratigraphic levels. These bioherms, with growth relief of about 1 m, are of ellipsoidal shape, with strongly inclined columns at their margins. Laminated shale or limestone fills the spaces between bioherms (Figs. 8a,c); in places, sandy limestone laps on to the bioherm margins, and then covers the whole biostrome or bed. Transverse sections of bioherms are rarely seen, except where dips are gentle: e.g. near Myrtle Springs oval bioherms occur, while at Arkaroola they are sinuous and irregular. Small, isolated bioherms only 30 cm wide also occur at Arkaroola.

Column Shape and Arrangement. There is great variability of column shape even within single specimens. Most commonly, columns are vertical or inclined, gently curved, non-parallel and bumpy, varying from subcylindrical to tuberous (Figs 1i–y; 2a–n; 8b,e,f; 9a–c). Columns vary in diam. from 1 to 8 cm, and swell and constrict moderately throughout their length. Transverse sections are commonly oval, variously elongated, lobate or rounded-polygonal, occasionally circular. Columns are up to 10 cm long between branches, but individuals attain a height of about 50 cm. The terminations of columns may be either rounded or pointed (Fig 1p,r,t,x,y). Columns are poorly developed in the bioherms at Arkaroola, where they are bridged over after a few centimetres of growth (Fig. 8f).

Branching is very frequent, variable, but most commonly subparallel (mostly α- and β-parallel, some γ-parallel) and moderately divergent (Figs 1i–y; 2a–n; 9a–c). In all specimens, there are a few branches which do not grow into large columns, but terminate as narrow, pointed projections, 1–4 cm long, often less than 1 cm wide (e.g. Fig. 1x,y). These are subordinate and may either be parallel to the main column, or diverge from it laterally.

Margin Structure: Columns are moderately bumpy; in general the bumps are low, rounded, 1–3 cm in diam. and with a relief of usually less than 0.5 cm. Bumps may grade into short pointed projections. Some columns from Myrtle Springs are rather smooth (Figs 1w,y). The margins of columns are mostly walled, but for short distances the wall may be absent. Short overhanging laminae and peaks are pre-

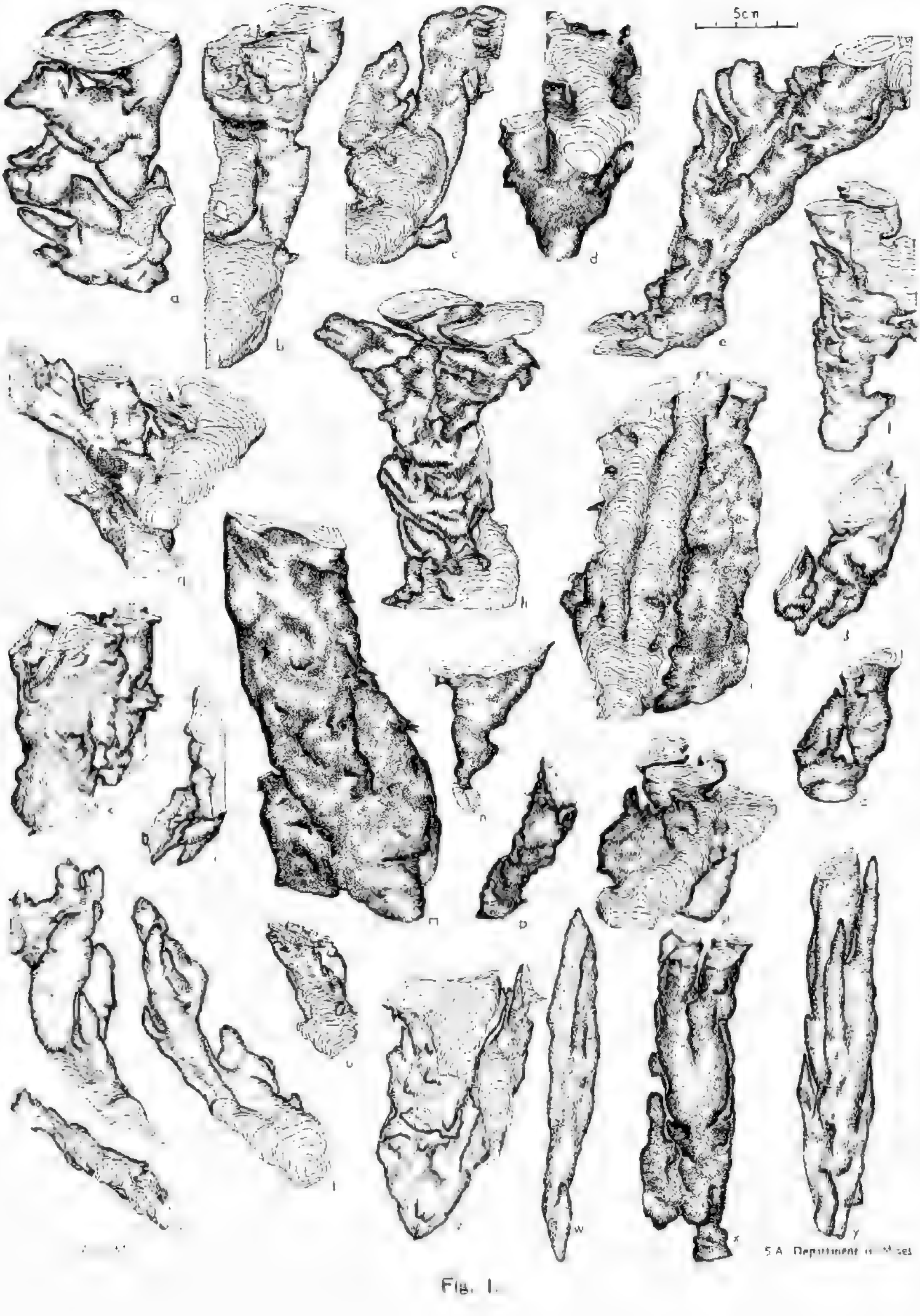

Fig. 1.

sent moderately frequently, while adjacent columns are sometimes linked by bridges of varying thickness. Some inclined columns at bioherm margins at Burr Well are largely unwalled (Fig. 8e). In many outcrops, columns are seen to be bridged over at the top. The wall is formed by the marginal portions of both steeply and gently convex laminae covering the lateral surface of columns, but the number of laminae participating is difficult to estimate, due to recrystallization of the wall zone. Well preserved specimens from Myrtle Springs show that up to 20 laminae may be involved, the wall zone here being up to 5 mm thick (Fig. 9b).

Lamina shape is highly variable (Fig. 5b), with a large spread of values of h/d from 0.2 to 1.3: the greatest variability is seen in single specimens at Myrtle Springs, and laminae from other areas fall within this range; 76% of laminae measured have h/d between 0.3 and 0.7 (Fig. 6b). The most steeply convex laminae occur in the pointed columns at Myrtle Springs, where they approach subconical shape; otherwise laminae are smoothly domed, rarely rectangular or flattened. On a finer scale, well-preserved laminae are smooth or very gently wavy; no primary wrinkling is seen, although in some specimens, recrystallization has embayed laminae so as to produce a secondary wrinkling.

Microstructure is best preserved in specimens from Myrtle Springs, where it is seen to consist of thin, even, light and dark laminae, which are generally continuous, but may be cut by small micro-unconformities. Both lamina types thin markedly and become more distinct towards the column margins. Laminae are especially prominent in the wall zone, where they are of more uniform thickness (0.05–0.1 mm), with smooth, parallel boundaries, but lens out gradually down the column margin (Fig. 9b). Here dark laminae, composed of an interlocking mosaic of xenotopic calcite, of grain size 0.006–0.02 mm, alternate with lighter laminae of similar texture and slightly coarser grain size (0.015–0.04 mm). In the central portions of columns, laminae are 0.1 to 0.5 mm thick, the pale laminae generally being thicker than the dark. The laminae are of similar texture and grain size to those at column margins, but the light laminae contain abundant irregular, xenotopic dolomite crystals of grain size 0.03–0.05 mm. Microstructures from other areas are less well preserved; frequently the finest laminae have been obliterated by greater dolomitization (e.g. Roebuck Bore, Fig. 9a), or by more pervasive recrystallization of the limestone. Small areas with unaltered very thin laminae usually occur as remnants of the original microstructure.

Interspaces: The sediment filling interspaces varies from area to area. At Myrtle Springs, columns are widely separated (1 to 10 cm apart), and the interspace sediment is layered, consisting of alternating bands of sand and micritic limestone. The micritic bands are homogeneous, 2–25 mm thick, and consist of slightly recrystallized xenotopic calcite (grain size 0.003–0.01 mm) with rare, scattered dolomite rhombs. In places, algal laminae form continuous bridges capping the tops of columns, but also occur as upward-concave laminated sediment between walled columns, indicating that they post-date the column growth. Such algal laminae may in turn grade up into new columns. Both the micrite and the algal laminae are scoured in places to a depth of up to 3 cm, and the channels so formed are filled with coarse sand, of grain size 0.5–2 mm, with ooids, minor lime mud, and cemented by fine, sparry and acicular calcite. The growth relief of columns must have exceeded about 5 cm above the surrounding sediment, which was formed by slow deposition of lime mud and periodic rapid deposition of coarse detritus. Intraclastic limestones (often sandy) occur at Roebuck Bore (here intraclasts are limestone while their matrix is dolomitized) and Burr Well (Figs. 9a; 8c). Intraclasts are randomly oriented, slightly rounded, structureless flat pebbles up to 1 cm long, consisting of recrystallized xenotopic calcite of grain size 0.01–0.03 mm. The matrix consists of equigranular, xenotopic dolomite of grain size 0.05–0.08 mm with minor fine quartz sand and iron-stained dolomitic pellets. Specimens from the middle member of the Wundowie Limestone at Arka-

Fig. 1. Reconstructions of *Linella*, Umberatana Group, Flinders Ranges; (a–h)—*Linella ukka*, Balcanoona Formation, Burr Well; (a, b, f, h)—S478; (c, e, g)—S477; (d)—S541; (i–q)—*Linella munyallina* Wundowie Limestone Member, Roebuck Bore; (j, k, l, n, q)—S431; (p)—S430; (i, o)—S428; (m)—S427; (r–v)—*Linella munyallina*, Wundowie Limestone Member, Burr Well: (r, t, v)—S486; (s, u)—S484, Inclined columns from bioherm margins; (w, x, y)—*Linella munyallina*, Wundowie Limestone Member, 8 km east of Myrtle Springs H.S. Holotype S495.

roola contain banded interspace sediment; the alternating bands, up to 1 cm thick, contain micrite and fine intrasparite respectively, suggesting periodic current action to rework lime mud fragments. In the upper member of the Wundowie Limestone at Arkaroola, interspaces are filled with homogeneous fine subangular quartz sand, cemented by minor calcite.

Secondary Alteration: Specimens from Myrtle Springs are best preserved, the chief alteration being partial dolomitization of light laminae. Alteration of the wall zone by recrystallization of calcite is common in all areas; the outer portions of laminae are recrystallized to an equigranular, hypidiotopic calcite mosaic. Where recrystallization is slight, a few relics of dark laminae are preserved in a sparry calcite mosaic, of grain size 0.03–0.05 mm, often with scattered dolomite crystals. With extreme recrystallization, the whole of a column may be affected, resulting in a coarse hypidiotopic mosaic of equidimensional, twinned calcite crystals, 0.5–2 mm diam. A secondary green clayey mineral forms an interstitial matrix between calcite crystals, and probably represents a segregation of impurities during recrystallization. Even in these cases, the wall is usually preserved as a thin layer of very fine calcite, and the interspace outside it is unaffected. These patches of coarse recrystallization, together with the fine calcite veins they grade into, apparently post-date the dolomitization of light laminae, since relics of this dolomite are preserved within them. Specimens from Roebuck Bore are very largely dolomitized, appreciable amounts of calcite being preserved only in the columns and in some intraclasts. The interspace matrix is completely dolomitized, dolomitization pre-dating stylolites and calcite veins.

Comparisons

The stromatolites from the Wundowie Limestone at Myrtle Springs, Burr Well, Roebuck Bore and the Willouran Ranges are identified as *Linella* on the basis of their branching, bumpy, tuberous columns and the presence of a wall and pointed projections. Specimens from Arkaroola are also included, although here the columnar beds are thin, and columns rapidly coalesce or are bridged over by wavy-laminated stromatolite. *Linella munyallina* is similar to *Kulparia* [illegible]*rensis* Preiss and *Kulparia costata* Preiss in having bumpy walled columns with pointed projections, but the columns of the latter two forms are more closely spaced, subcylindrical and always parallel, with no divergent branching. *Linella munyallina* is distinguished from *L. ukka* Krylov by its dominantly parallel branching, fewer pointed projections, the presence of moderately frequent peaks, bridges and unwalled patches of columns. *Linella simica* Krylov has ribbed columns, while *L. avis* Krylov has more gnarled, thickly walled columns with very frequent pointed projections. *L. zhuica* Shenfil' rarely has a wall and has markedly divergent branching.

Distribution: Widespread in the Wundowie Limestone, Umberatana Group, of the Northern Flinders Ranges: near the West Mount Copper Mine, 5 km east of West Mount Hut, 9 km north of Termination Hill and at Lake Arthur, Willouran Ranges; middle member of the Wundowie Limestone, 8 km east of Myrtle Springs; lower member of the Wundowie Limestone, Burr Well; middle member of the Wundowie Limestone, Roebuck Bore; and lower and upper members of the Wundowie Limestone, 2 km south of the Arkaroola Airstrip. A small specimen from the South Australian Museum collection (supplied by Mr. N. Pledge), found in the Etina Formation near Artipena Hut, Central Flinders Ranges, east of Martin's Well may also be *Linella munyallina*.

Age: Late Adelaidean, correlated with either the Late Riphean or Vendian of the USSR.

Fig. 2. Reconstructions of *Linella munyallina*, *Omachtenia utschurica* and *Tungussia etina*. (a–n)—*Linella munyallina*, Wundowie Limestone Member; (a, b, c)—Holotype S495, 8 km east of Myrtle Springs H.S.; (d, i)—S549, Lake Arthur, south-western Willouran Ranges (Collected by Mr. B. Murrell); (e)—S485, Burr Well; (f)—S556, West Mount Hut, Willouran Ranges (Collected by Mr. B. Murrell); (g, h)—S486, Burr Well; (j)—S552, Lake Arthur, South-western Willouran Ranges (Collected by Mr. B. Murrell); (k)—S544, 3 km east of Copley; (l)—S555, West Mount Hut, Willouran Ranges (Collected by Mr. B. Murrell); (m)—S566, 9 km north of Termination Hill (Collected by Mr. B. Murrell); (n)—S294, Munyallina Valley; (o–r)—*Omachtenia utschurica*, from the uppermost beds of the Tapley Hill Formation, Depot Creek; (o, p, r)—S399; (q)—S392. Note: Not all bridges could be shown on diagrams; (s)—S158, *Tungussia etina*, Etina Formation, 5 km east of Blinman; (t)—S157, *Tungussia etina*, Etina Formation, Enorama Creek.

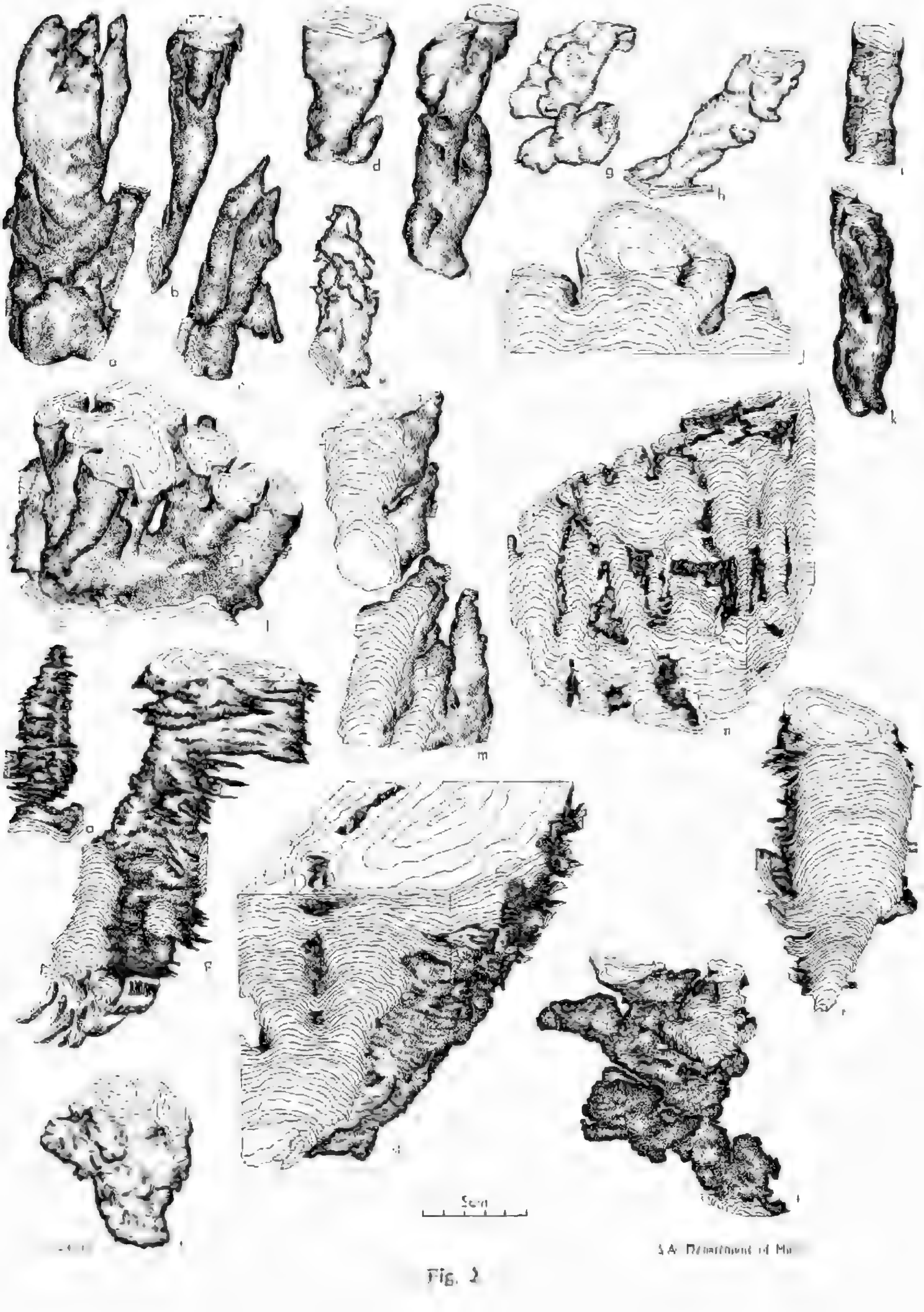

Fig. 2

Group OMACHTENIA Nuzhnov
Collenia omachtensis Nuzhnov 1960: 1422.
Omachtenia Nuzhnov 1967: 131.

Type Form: Omachtenia omachtensis Nuzhnov, from the Omakhtin Suite of the Uchur Basin, Uchuro-Maya region, S.E. Siberian Platform.

Diagnosis: Columnar-layered stromatolites consisting of cylindrical and subcylindrical unwalled columns, frequently widening upwards, with numerous cornices and bridges linking several columns. Branching is mainly α-parallel; columns are usually vertical, sometimes radiating or curved.

Content: Omachtenia omachtensis Nuzhnov, *O. utschurica* Nuzhnov and *O. givunensis* Nuzhov.

Age and Distribution: Early Riphean in the Uchuro-Maya region of the USSR, but in South Australia, *O. utschurica* occurs in rocks correlated with the Late Riphean.

Omachtenia utschurica Nuzhnov 1967: 133.
FIGS. 2o–r, 5c, 6c, 9d,e, 10a–c

Material: Nine specimens from Depot Creek and Mundallio Creek.

Description

Mode of Occurrence: The stromatolites form small lenticular bioherms repeatedly intercalated in very finely laminated calcareous siltstones of the top of the Tapley Hill Formation, south-western Flinders Ranges. Commonly discrete, bioherms 2 to several tens of metres wide, develop on erosional surfaces on the underlying laminated siltstones (Preiss 1973b, pl. 28) and are closely associated with channels filled with imbricated flat-pebble breccias, often surrounding the bioherm. Bioherms are generally less than 1 m thick. All gradations from flat-laminated to domed, club-shaped, pseudocolumnar and columnar stromatolites exist (Figs. 2o–r, 9d,e). Where columns are developed, their axes are mostly vertical, but their sides may slope in various directions, and overhang the interspaces (Fig. 10a).

Column Shape and Arrangement: Where columns are discrete, they are generally subcylindrical, sometimes widening upwards, either vertical, or radially arranged. Columns are rarely completely discrete for more than a few centimetres, but are either linked by bridges or completely coalesced. They may pass laterally as well as vertically into laterally linked or flat-laminated stromatolites, which may in turn pass into flat-pebble breccia, at least some of the intraclasts being reworked chips of algal mats. Columns commonly commence growth upon some irregularity of the substratum, e.g. on the erosional surface of the underlying silts or on upturned flat pebbles (Fig. 2p). Columns are mostly circular in cross section, 2–15 cm in diam., but may be complexly lobate.

Branching: True branching into discrete columns is moderately rare, but may be multiple. Branching may be α-, β- or γ-parallel, sometimes markedly γ-parallel, or slightly divergent. Branched columns are frequently bridged over, or coalesce, after a few centimetres.

Margin Structure: Column margins are extremely irregular with numerous short cornices, bridges and overhanging laminae, which drape over the periodically deposited interspace sediment (Fig. 10b). Bridges consist of from one to many laminae, up to several centimetres thick. Over intervals without bridges or overhanging laminae (which may represent periods of growth during which interspaces were not filled) the column margin bears small ribs and bumps. Nowhere is a wall developed.

Lamina Shape: Laminae are never steeply convex: in most cases, they are flat-topped, with down-turned edges, i.e. rhombic or rectangular. They may grade both laterally and vertically into continuous flat laminae. Typical lamina shapes are illustrated in Fig. 5c. Of 40 laminae measured, 83% have h/d between 0.2 and 0.4 (Fig. 6c). If the growth of a column is asymmetrical, laminae are also asymmetrical, but growth always proceeds vertically, although column sides may be sloping. Laminae are smooth, very rarely wrinkled or finely wavy, occasionally with micro-unconformities.

Microstructure is distinctly banded and consists of an alternation of sparry and pelletal calcite laminae and fine, granular dolomite laminae (Fig. 10b,c). Dolomite laminae are 0.2 to 1.0 mm thick, and thin only slightly towards column margins. Their upper and lower boundaries are more or less parallel; the upper boundary is always sharp and often smooth, while the lower is usually gradational into pelletal laminae. Dolomite laminae, with almost no calcite, consist of granular, equidimensional hypidiotopic to idiotopic dolomite, grain size 0.01–0.03 mm. At the boundaries, euhedral dolomite crystals protrude into the adjacent sparry laminae. In places, several thin dolomite laminae are grouped to form macrolaminae up to 2 mm thick; here the dolomite laminae are separated by thin, discontinuous lenses of sparry calcite, which may be open space fillings (Fig. 10b).

Dolomite layers are overlain with sharp and sometimes slightly eroded contact by coarsely sparry calcite laminae varying in thickness from 0.1–1.00 mm, which pinch and swell and may lens out laterally. The calcite is hypidiotopic to xenotopic, transparent, consisting of frequently twinned crystals, grain size 0.04–0.2 mm. In places there are lenses of coarser, polygonal calcite of grain size up to 0.6 mm, and rarely, of acicular calcite. Scattered very small dolomite rhombs occur in places. Sparry calcite laminae grade up into pelletal laminae, consisting of subrounded pellets 0.06–0.1 mm in diam., of fine grained hypidiotopic dolomite (0.01–0.02 mm grain size), with clear, xenotopic calcite cement filling the voids. Pellets become more tightly packed upwards, so that they grade into homogeneous dolomite laminae. In one specimen (Fig. 10c) pelletal laminae are poorly developed.

Interspaces between columns are filled with intraclast and pellet grainstones, periodically interrupted by bridging laminae. Essentially the same sediment occurs outside the bioherms in channels cut into the underlying silts, but there it is bedded, and clasts are imbricated. In the interspaces, the sediment is largely unbedded (Fig. 10a,b) consisting of flat intraclasts up to several centimetres long, 1–4 mm thick, randomly oriented and loosely packed with numerous round to ovoid pellets, 0.15–0.3 mm in diam. Pellets and intraclasts consist of equigranular hypidiotopic dolomite similar to that of the dolomite laminae; the intraclasts were probably derived from the erosion of the flat-laminated variety of the stromatolites, while pellets are interpreted as comminuted and rounded, repeatedly reworked dolomite intraclasts. Allochems must have been in part matrix supported, but only locally is a lime mud matrix preserved. Most grains are cemented by a clear, sparry cement of xenotopic inequigranular calcite, grain size up to 0.4 mm. What must have been primary lime mud supporting scattered intraclasts now consists of recrystallized hypidiotopic calcite, grain size 0.05–0.1 mm with scattered dolomite rhombs. In places, large allochems or overhanging column margins sheltered the underlying areas from settling mud, and these are now filled with coarse, open space filling sparry calcite.

Secondary Alteration: Dolomite pellets and intraclasts were probably reworked as dolomite, i.e. the original sediment was affected by early diagenetic dolomitization and then redeposited; many intraclasts are long and flat, and could not have withstood transport without being lithified. These allochems were partly supported by lime mud, and partly winnowed, leaving open spaces filled with sparry cement. The time of dolomitization of the dolomitic stromatolite laminae is not clear; dolomite pellets are cemented with sparry calcite, suggesting that the sediment was brought in as dolomite. But dolomite rhombs in the laminae appear to post-date the calcite cement. In addition, dolomite rhombs occur scattered throughout the recrystallized lime mud (now microspar), and the sparry, open space filling calcite. It is likely that minor secondary dolomitization affected the whole sediment after its deposition. Post-depositional pyrite cubes, 0.08–0.20 mm wide, are scattered throughout the rock. Stylolites are rare, and are restricted to broadly conformable types which follow bridging laminae between columns.

Comparisons

The columnar and columnar-layered portions of this stromatolite accord with Nuzhnov's description of *Omachtenia* in having cylindrical or sub-cylindrical columns with frequent cornices and overhangs on the lateral surfaces, which are linked by numerous bridges and layers common to several columns. Branching in both is dichotomous or multiple, usually α-parallel. Columns are usually vertical, or rarely, radiating. As the domed and flat-laminated stromatolites cannot be separated from the columnar and columnar-layered portions, these must be included as environmental variations of *Omachtenia*. The stromatolites differ from *Jurusania* Krylov and *Kussiella* Krylov in having more irregular, more frequently branching columns repeatedly linked by bridges. The repeated bridging and characteristic thick, pelletal laminae distinguishes them from the basal portions of *Inzeria conjuncta* and *Acaciella augusta*. *O. utschurica* Nuzhnov differs from *O. givunensis* Nuzhnov in having more gently convex laminae (h/d less than 0.5). *O. omachtensis* Nuzhnov has generally narrower columns and some short, lateral outgrowths, and thinner, non-pelletal laminae. *O. utschurica* from the Tapley Hill Formation is extremely similar to *O. utschurica* from the Uchur River, USSR, in gross shape, type of bridges and lamina shape, but has slightly thicker pelletal laminae. (Pellets may also be present in the type material, as in Nuzhnov 1967, Pl. 11(4)). *Omachtenia* closely resembles *Schancharia* Korolyuk in gross shape, lamination and bridging; *Schancharia*, however, apparently has a thin, one-layered wall (Korolyuk, 1960).

Distribution: The Omakhtin Suite of the Uchur River, S.E. Siberian Platform, and the upper Tapley Hill Formation, Depot Creek and Mundallio Creek, S.W. Flinders Ranges, S. Aust.

Age: Early Riphean in the USSR, but here it is Late Adelaidean, in beds correlated by other stromatolites with the Late Riphean.

Group TUNGUSSIA Semikhatov

Collenia suchotungusica Semikhatov 1960: 1481.

Tungussia Semikhatov 1962: 205.

Type Form: Tungussia nodosa Semikhatov, from the Sukhotungusin Suite, Yenisei Mountains.

Diagnosis: Tuberous to subcylindrical, horizontal to vertical columns with frequent, multiple, markedly divergent branching; lateral surface is smooth or with small peaks, and at least locally with a wall.

Content: T. nodosa Semikhatov, *T. confusa* Semikhatov, *T. sibirica* Nuzhnov, *T. inna* Walter and *T. erecta* Walter. *T. bassa* is a lateral variant of *Linella ukka* Krylov, *T. enpiggeni* Raaben and *T. russa* Raaben are insufficiently described and illustrated to allow comparison, and the description of *T. arctica* Raaben is unavailable. New forms are *T. etina* and *T. wilkatanna*.

Age: Middle to Late Riphean, and probably Vendian.

Tungussia etina f. nov.

FIGS. 2s,t, 3a–m, 4a,b, 5d, 6d, 10d,e, 11a–e, 12a

Material: Twenty-eight specimens from Mt Chambers Gorge, Teatree O.S., Blinman, Martin's Well, Enorama and Arkaba areas.

Holotype: S435 (Figs. 3i,1, 4a,b, 11c), Mt Chambers Gorge.

Name: After the Etina Formation, in which the stromatolites partly occur.

Diagnosis: Tungussia with a wide variation of branching style from subparallel to markedly divergent, a thin, interrupted wall, and thick, pinching and swelling, wavy laminae. Coarse detritus can be incorporated in light laminae, if it was available during growth.

Description

Mode of Occurrence: The stromatolites occur in irregular tonguing bioherms and lenticular beds in the Etina Formation and its extensions in the Northern Flinders Ranges. Exposures are often inadequate to determine the exact shape of the lenses, but generally they are discrete isolated bodies, surrounded by sandy and oolitic limestones. In the occurrence near Mt Chambers Gorge, the columnar stromatolites overlie irregularly laminated sandy and oolitic limestone (the contact is now stylolitic), and form a lens up to 2 m thick in its thickest part. In places, growth continued on the top of the lens in the form of irregularly wavy and pseudocolumnar stromatolites. At the margins of the bioherm, columns grade laterally into pseudocolumns and wavy laminae, which intertongue with oolitic limestone. At Teatree O.S., the stromatolitic bed again intertongues with oolitic limestones, but here columns are more inclined at the bioherm margins than in their centres. Similar relations of stromatolitic bioherms intertonguing with sandy ooid and intraclast grainstones were observed in the Etina Formation in the Arkaba Hills, Enorama Creek (Fig. 10c), Blinman and on the south-western flank of the Enorama Diapir. However, at many locations in the Central Flinders Ranges, the columnar portions are poorly developed.

Columnar Shape and Arrangement: Well developed columns persist vertically for more than 10 cm only in the sections at Mt Chambers Gorge, Enorama Diapir and at Teatree O.S.; elsewhere short, irregular columns quickly grade up into linked pseudocolumns. At Mt Chambers Gorge, the orientation of columns varies from vertical to variously inclined, to subhorizontal (Fig. 10d). Columns from the Teatree O.S. locality are also variously inclined, but rarely subhorizontal; some are subparallel (Figs 2s,t, 12a). Columns from all areas are tuberous, bumpy, swelling and constricting, or,

Fig. 3. Reconstructions of *Tungussia etina*, Umberatana Group, Central and Northern Flinders Ranges. (a)—S286, Wundowie Limestone, near Teatree O.S.; (b)—S158, Etina Formation, 5 km east of Blinman; (c)—S561, Etina Formation, S.E. margin of Enorama Diapir; (d)—S522, Etina Formation, Arkaba Hills; (e)—S526, Balcanoona Formation, near Mount Chambers; (f, g, h)—Wundowie Limestone Member, near Teatree O.S.; (f) S441, (g) S444, (h) S440; (i, j, k, m)—Balcanoona Formation, near Mount Chambers; (i, l)—Holotype, S435; (j)—S436, (k)—S525, (m)—S524.

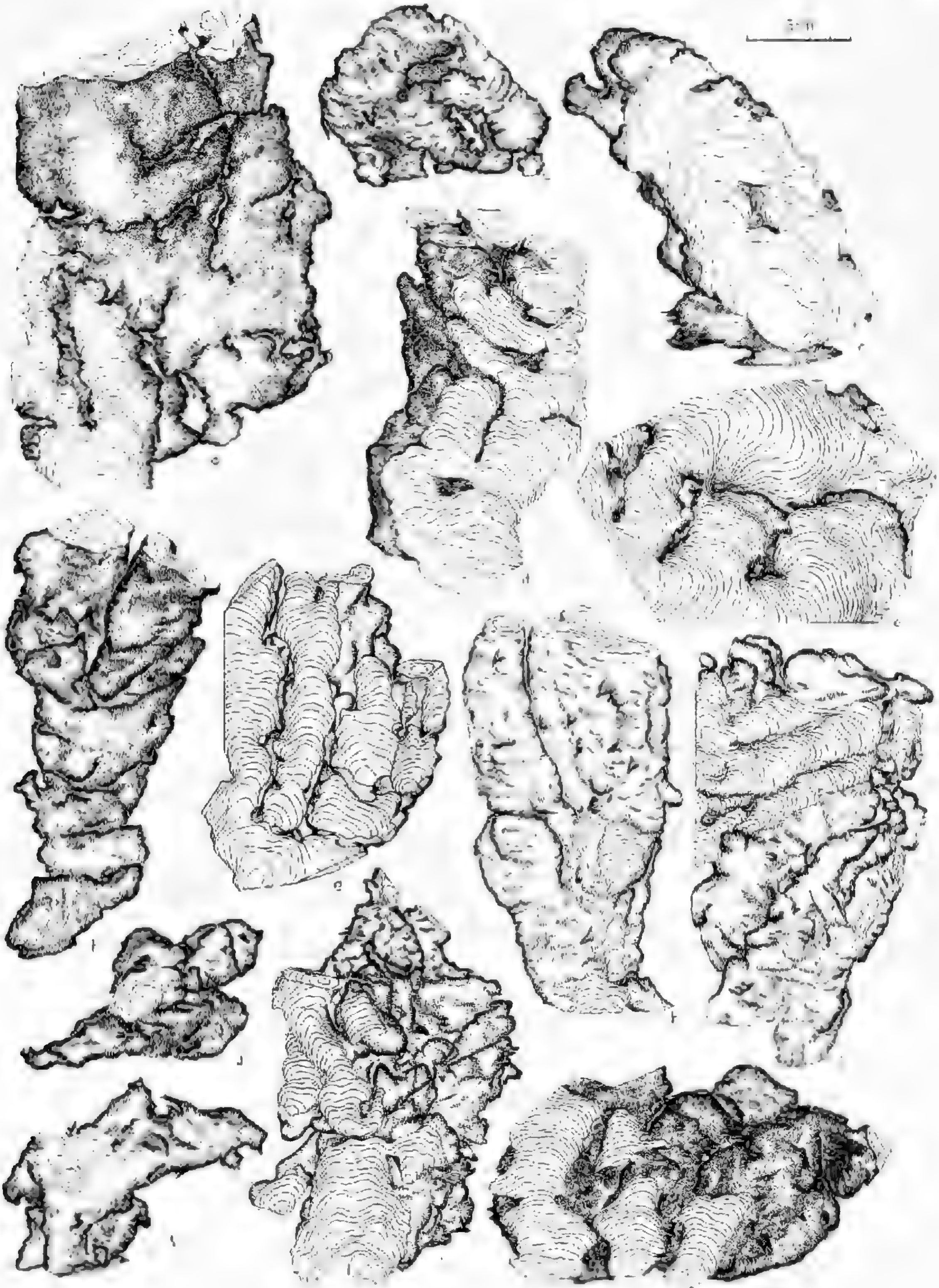

Fig. 3.

S.A. Department of Mines

less commonly, straight, subcylindrical. Short columns from Central Flinders localities are frequently bulbous (Fig. 11d). Bumps and swellings are generally broad and rounded, while constrictions sometimes take the form of deep indentations into the main column, at points of branching (Fig. 3a,f,h). Some columns branching from the main column are only a few centimetres long, with either pointed or rounded terminations (Fig. 3a). Columns vary greatly in diameter from 1 to 10 cm, the largest occurring at Mt Chambers Gorge. Transverse sections vary from elliptical to complexly lobate; circular sections are rare.

Branching is very frequent and highly variable; even within single specimens, both parallel and markedly divergent branching may occur. Specimens from Mt Chambers Gorge have predominantly multiple, markedly divergent branching, although columns may become subparallel soon after branching (Fig. 3m). At Teatree O.S., markedly divergent branching and parallel or slightly divergent branching occur together (Figs. 3f,g,h, 11a, 12a). Columns from Enorama Creek are frequently truncated by stylolites parallel to overall bedding, so that the style of branching is obscured. Columns from this locality that allowed reconstruction (Fig. 2i), show markedly divergent branching.

Margin Structure: Primary margin structure is frequently obscured by stylolites; in some specimens from Arkaba, Teatree O.S. and Mt Chambers Gorge, almost no column margins are preserved. Where columns are relatively unaffected by stylolites, they are seen to bear thin, interrupted walls, involving two or three laminae only, or very locally, multilaminate walls, e.g. Enorama Creek and Teatree O.S. (Figs. 11a,h,i). But the latter are affected by pervasive recrystallization, so that commonly only the outer margin of the wall is preserved. Adjacent columns frequently coalesce, or are linked by massive bridges up to several centimetres thick. Bridges and overhanging laminae are common on unwalled portions of columns, especially from Mt Chambers Gorge (Fig. 3m). Column margins are gently bumpy, with occasional short transverse ribs. Most of the surface irregularity of some specimens from Teatree O.S. is due to stylolitic solution of column margins (e.g. Fig. 3a).

Lamina Shape is most commonly moderately steeply convex (Fig. 5d). Measurement of h/d ratio is difficult in some specimens due to removal of column margins by stylolitic solution; thus measured ratios may be too low in these cases. Of 131 laminae measured, 93% have ratios of h/d between 0.2 and 0.7, the mode being between 0.3 and 0.4. Laminae are moderately to markedly wavy, the undulations having a wavelength of 3–10 mm, and amplitude 1–5 mm. Laminae are lenticular, and pinch and swell markedly over short distances; this irregularity is caused at least in part by erosional micro-unconformities (Fig. 11c,e).

Microstructure: A broad, irregular lamination is well preserved in some specimens from Teatree O.S., Blinman, Enorama Creek and Mt Chambers Gorge, where thick, wavy, pinching and swelling light laminae alternate with darker thin, fine-grained laminae frequently with clay or iron oxide impurities. *Light laminae* vary rapidly in thickness from 0.2–2.00 mm, and frequently lens out laterally; few extend across a full column width. Very commonly, the light laminae are truncated by erosion surfaces, especially in specimens from Mt Chambers Gorge (Fig. 11e). They are composed of equigranular xenotopic to hypidiotopic mosaic calcite, grain size 0.006–0.03 mm. Occasionally, coarser detritus is incorporated, if it was available. For example, the Enorama Creek stromatolites contain up to 50% of ooids and coated grains, 0.3–1.00 mm in diam., within their light laminae. Elongated ooids and coated grains are aligned parallel to the lamination, and are always supported by the finer sediment of the stromatolitic laminae. Ooids are extremely abundant in the interspaces. Specimens from Teatree O.S. contain very few ooids, but here the supply was not great, as seen from the preponderance of lime mud in the interspaces. At Mt Chambers Gorge, ooids are absent both in interspaces and stromatolite laminae, but fine sand present in interspaces is also incorporated into laminae. These observations suggest that the algal mats were capable of trapping coarser detritus, if it was brought to the site. The thinner *dark laminae* are 0.05–0.15 mm thick, and composed of very fine micritic calcite, of xenotopic, equigranular texture and grain size 0.003–0.01 mm. At Mt Chambers, the dark laminae are emphasized by very fine, hypidiotopic ferruginous dolomite concentrated along them. In places (e.g. Blinman), dark laminae with sharp lower boundaries grade up into light laminae (Fig. 11d). At Arkaba Hills, the dark laminae are largely stylolitic.

Interspaces: Columns are moderately closely spaced, interspaces 5 mm–2 cm wide. The type of sediment filling the interspaces varies in the different areas, and its relation to the quantity of detritus in laminae has already been discussed. At Mt Chambers Gorge, interspaces are filled mainly with slightly dolomitized and recrystallized partly laminated lime mud, with a few bands up to 2 cm thick of very fine, subangular quartz sand. Flat intraclasts up to 2 cm long are in places stacked vertically in interspaces between walled columns, indicating a minimum relief of 2 cm. Discrete areas of intraclast grainstone suggest that after column growth, coarser detritus was occasionally washed in between times of settling of lime mud. At Teatree O.S. interspaces contain poorly bedded micritic limestone and ooid wackestone; in one specimen (Fig. 11h), these alternate in 5 mm bands. Ooids are commonly preserved only as moulds infilled with sparry calcite. Unbedded fine or medium sand with a micrite matrix commonly fills interspaces in the Etina Formation. At Blinman, the sand contains rounded medium grained quartz, red feldspar and green pellets consisting of a chloritic mineral. Since little sand is incorporated into the stromatolitic laminae, the interspaces were probably rapidly filled after, not during, column growth. Interspaces at Enorama Creek are filled with ooid grainstone exclusively—the allochems are chiefly ooids with a single outer lamina and coated, flat intraclasts. Oolitic laminae may be partly detached, perhaps due to the growth of sparry cement.

Secondary Alteration: Specimens from Blinman and Enorama Creek are the best preserved, the chief alteration being the formation of calcite veins, cut by later stylolites parallel to bedding. Dolomitization is restricted to specimens from Teatree O.S. and Mt Chambers Gorge: rhombs of dolomite varying from 0.01–0.015 mm, sometimes ferruginous, are scattered throughout both lamina types. Ferruginous dolomite is concentrated in the dark laminae and the interspace sediment at Mt Chambers Gorge. Small areas of recrystallization of fine grained calcite to grumous texture are present in all specimens; the wall zone especially may be almost totally recrystallized, leaving only the outer lamina preserved. Light laminae are completely recrystallized in one specimen from Mt Chambers Gorge. Stylolites on column margins are very frequent at Teatree O.S., Arkaba Hills and Martin's Well, postdating the recrystallization of laminae and replacement of ooids by sparry calcite, but apparently pre-dating dolomitization. Local large solution cavities are rimmed with zoned ferruginous dolomite rhombs, then filled with coarse, granular sparry calcite.

Comparisons

The stromatolites are characterized by a very wide variation of gross morphology, especially branching, which distinguishes them from all parallel-branching stromatolites, although some resemble *Inzeria* Krylov in having deep indentations into the main column at branching. They are assigned to the group *Tungussia* on the presence of markedly divergent branching, subhorizontal columns, and thus differ from the other divergent branching groups *Linella* Krylov, *Baicalia* Krylov, *Anabaria* Komar, *Poludia* Raaben and *Parmites* Raaben. *Linella* has very numerous pointed projections, and columns are subhorizontal only in the marginal portions of bioherms. *Baicalia* differs in having chiefly ragged, unwalled, margins, with frequent overhanging laminae. *Anabaria* has consistent, slightly divergent branching, and cylindrical columns. The columns of *Poludia* are complexly curved and intertwined, while those of *Parmites* are anastomosing.

Tungussia etina differs from all other forms of the group in its great variation of branching style, and its microstructure. Some specimens closely resemble *Tungussia inna* Walter in having oolitic, wavy laminae, but *T. etina* is distinguished by its distinct thicker, pinching and swelling lamination and variable branching.

Distribution: Etina Formation and equivalents, Umberatana Group, Central and Northern Flinders Ranges; Balcanoona Formation at Mt Chambers Gorge; Wundowie Limestone at Teatree O.S.; Etina Formation near Blinman, Martin's Well, the S.E. flank of the Enorama Diapir, Enorama Creek and the Arkaba Hills area.

Age: Late Adelaidean, correlated with the Late Riphean or Vendian of the USSR.

Tungussia wilkatanna f. nov.

FIGS. 4c–i, 5e, 6e, 12b–e

Material: Five specimens from Depot Creek and Mundallio Creek.

Holotype: S412 (Figs. 4f, 12e), Depot Creek.

Name: After Wilkatanna H.S., 8 km northwest of the type locality.

Diagnosis: *Tungussia* with smooth to gently bumpy subcylindrical to tuberous, frequently walled columns, with markedly divergent multiple branching and continuous thinly banded, hemispherical laminae.

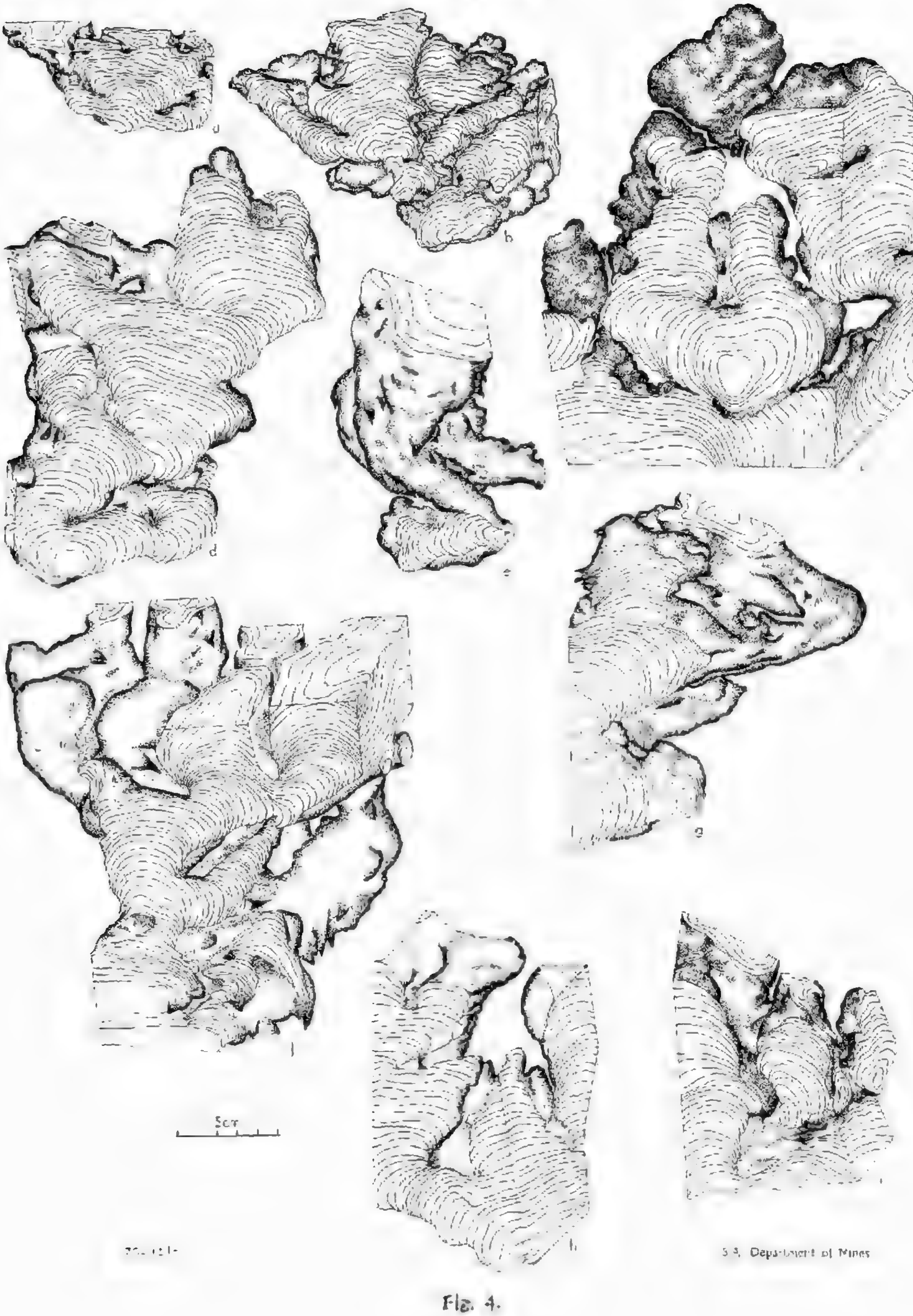

Fig. 4.

Description

Mode of Occurrence: The stromatolites occur in pale pink to white pure dolomites and possibly also in dark grey dolomites, as extensive biostromes, 0.3–2 m thick, interbedded in laminated siltstones and shales. The upper surfaces of biostromes are irregular, undulating, and in places, erosional. Stromatolitic columns arise from flat-laminated or cumulate bases (Fig. 12c), growth frequently commencing upon the eroded surface of the underlying shale. In some beds, only the flat-laminated or cumulate stage of growth is attained, in others, up to 2 m thickness of columns develops. Columns are either bridged over at the top by laterally linked hemispheroids, or eroded. Columnar portions may grade laterally along the biostrome into laterally linked hemispheroids.

Column Shape and Arrangement: Columns are subcylindrical to tuberous, bumpy, 2–10 cm in diam., with low broad swellings and constrictions; portions of columns widen rapidly above a constriction (Fig. 4c,d,f). Cross-sections vary from subcircular to highly lobate. The orientation of columns is highly variable, both horizontal and vertical columns being common. Individual columns are 5–20 cm high, but the whole structure may attain a height of 2 m.

Branching: Both vertical columns and broad cumuli may arise from the flat-laminated base. These typically give rise to a number of horizontal columns, from which in turn either vertical columns branch upwards, or the horizontal columns themselves turn sharply upwards (Fig. 4c–i). Columns are frequently constricted at branching, and then expand upwards rapidly. Multiple, markedly divergent, branching from one point is common.

Margin Structure: The lateral surface bears numerous broad bumps of up to several centimetres (Fig. 4c), but in places columns are quite smooth (Figs. 4f, 12e). Overhanging laminae are relatively rare, and any peaks and cornices present are only a few millimetres long (Fig. 4f). A wall is usually present but may be absent; unwalled areas are relatively smooth or finely fringed, the laminae abutting against the column margin at various angles (Fig. 12b,d). In walled areas, the laminae gradually thin and cover the surface for a distance of up to 1 cm. The wall varies in thickness from 1 to 10 laminae (Fig. 12e). Bridges become prominent near the top of the structure.

Lamina Shape is mostly hemispherical, but gently convex laminae occur in wide columns and in some horizontal columns, especially in unwalled portions. Laminae are smoothly curved, without sharp flexures, their shape being inherited from underlying laminae. Micro-unconformities occur, but are mostly only slight. Fig. 5e illustrates some representative lamina shapes. 83% of laminae have h/d between 0.2 and 0.5, the mode (33%) being between 0.3 and 0.4 (Fig. 6e). In places laminae develop two crests, anticipating branching. Near the margins of columns, laminae thin, and either abut against the margin (in places eroded) or bend over to form a wall. Laminae are either smooth or very gently undulating, with amplitude not exceeding one millimetre.

Microstructure is best preserved in silicified portions of columns; it is finely banded, consisting of alternating thin continuous dark and light laminae; continuity is broken only by micro-unconformities (Fig. 12e). In the less well preserved dolomitic stromatolites, the finest laminae are frequently obliterated and macrolaminae tend to predominate (Fig. 12b). *Light laminae* vary in thickness from 0.05–0.2 mm, most commonly 0.05–0.1 mm, but thin towards the column margins where they form the wall. The upper and lower boundaries are parallel, and usually distinct and smooth. No unequivocal detrital grains were seen; some thicker pale laminae are of finely grumous texture, representing partially recrystallized dark macrolaminae. Well preserved light laminae in silicified columns consists of extremely fine transparent chert—a xenotopic aggregate of equidimensional quartz grains, 0.001–0.01 mm in diam. Where preserved as carbonate, the light laminae consist of xenotopic to hypidiotopic dolomite of equidimensional 0.005–0.02 mm grains. *Dark laminae* are generally thinner than light laminae (0.02–0.2 mm, most commonly 0.02–0.08 mm). Where well preserved they have smooth, distinct boundaries, and are quite continuous, but in parts of dolomitic columns, they are preserved only as chains of elongated lenses, 0.1 to 0.5 mm long (Fig.

Fig. 4. Reconstructions of *Tungussia etina* and *Tungussia wilkatanna*. (a, b)—*Tungussia etina*, Holotype S435, Balcanoona Formation, near Mount Chambers; (c–i)—*Tungussia wilkatanna*, Skillogalee Dolomite, Southern Flinders Ranges; (c, h)—S169, Depot Creek; (d)—S323, Mundallio Creek; (e)—S410, Depot Creek; (f)—Holotype, S412, Depot Creek; (g)—S408, Depot Creek; (i)—S209, Depot Creek.

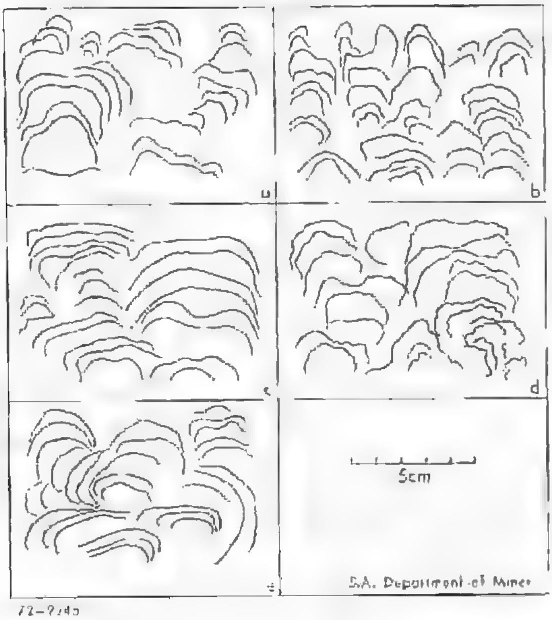

Fig. 5. Examples of Lamina shapes of stromatolites, traced from thin sections. (a)—*Linella ukka*; (b)—*Linella munyallina*; (c)—*Omachtenia utschurica*; (d)—*Tungussia etina*; (e)—*Tungussia wilkatanna*.

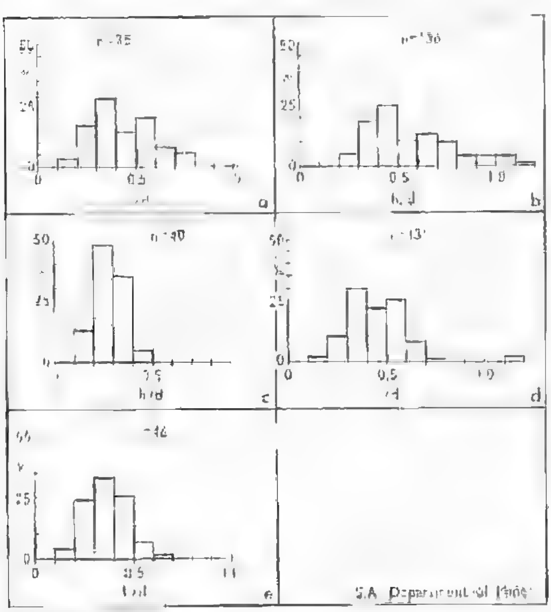

Fig. 6. Frequency distribution of lamina convexities for stromatolites illustrated in Fig. 5

12b). Silicified dark laminae consist of extremely fine, pale brownish-grey organic stained chert, of grain size 0.001–0.005 mm. Carbonate laminae consist of xenotopic dolomite of equidimensional 0.003–0.005 mm grains. Macrolaminae, 1–3 mm thick, consisting of up to 10 light-dark lamination pairs, occur only in the dolomitic portions of columns (Fig. 12b). In places, the fine internal lamination of macrolaminae is obliterated almost entirely, but these grade laterally into unaltered light and dark, very thin laminae.

Interspaces: The distances between neighbouring columns vary from several millimetres to several centimetres. The interspaces are filled with almost completely unbedded intraclast wackestone. Clasts vary from 0.5–2 cm; most are well rounded, and composed of homogeneous dolomicrite. Some are partially recrystallized to grumous-textured dolomite. Long, flat intraclasts, 0.5–1 mm thick, up to 2 cm long, are common near the base of one specimen; these are commonly replaced by coarse sparry hypidiotopic dolomite. Intraclasts are randomly oriented, loosely packed and generally matrix-supported.

Secondary Alteration: All definitely identified occurrences are found in pale pink to white dolomites; other specimens from dark grey dolomites at Depot Creek probably also belong to this group but are inadequate for reliable identification. The dolomite generally preserves most fine structure (as does the Skillogalee Dolomite of many other areas), but in places is significantly recrystallized. Silicification of portions of columns occurred after the growth of whole columns, but before partial alteration of the surrounding carbonate, since it best preserves the finest lamination. In places it is possible to trace unaltered very thin laminae from silicified to carbonate portions of columns; in the latter, only broad light and dark macrolaminae are preserved. The dolomitic nature of the whole (unsilicified) sediment suggests either penecontemporaneous dolomitization (during stromatolite growth) or trapping of dolomitized lime mud. Silicification therefore probably post-dates dolomitization. Grumous textures are developed sporadically throughout stromatolite and interspace sediment, and were probably formed by partial recrystallization during later diagenesis. Irregular stylolites, both cutting columns and following column margins, post-date the development of grumous texture. They are commonly rich in limonite, and, in places, pale green chlorite.

Comparisons

The stromatolites are assigned to the group *Tungussia* on the basis of their multiple, markedly divergent branching and frequent horizontal and gently inclined columns. These characters, in addition to a consistently smoother margin structure and frequent presence of a wall, distinguish them from *Baicalia burra* which occurs elsewhere in the Skillogalee Dolomite. *Tungussia wilkatanna* is differentiated from *T. nodosa* Semikhatov by its smoother column margins, smoother, consistently hemispherical and never disharmonic laminae. It resembles *T. sibirica* Nuzhnov in having numerous horizontal columns with upturned ends, but is distinguished by its smoother margin and presence of a wall. *T. wilkatanna* is distinguished from *T. bassa* Krylov in lacking long horizontal columns, and in occurring independently, not as a lateral variant of *Linella ukka* Krylov. Unlike *T. erecta* Walter, it lacks long erect columns, and is distinguished from *T. luna* Walter by its smooth laminae. *T. wilkatanna* most closely resembles *T. confusa* Semikhatov, but is distinguished by its thinner, more continuous laminae of predominantly hemispherical shape. *T. wilkatanna* has more regular and discrete columns of constant shape and branching than *T. etina*, and has thinner, more continuous, smoother laminae.

Distribution: In the lower third of the Skillogalee Dolomite, Burra Group; South-western Flinders Ranges: Depot Creek and Mundallio Creek. Small specimens possibly to be included, come from near the base and near the top of the formation.

Age: Early Adelaidean.

Acknowledgments

I am indebted to Prof. M. F. Glaessner for supervising this study, to the support given by the Centre for Precambrian Research, University of Adelaide, and to Dr M. R. Walter for discussions and collaboration. Messrs. B. Murrell and N. S. Pledge kindly supplied me with specimens, and Mr R. P. Coats indicated several stromatolite localities. Drafting by the Drafting Branch, Department of Mines, and by my wife is gratefully acknowledged. This paper is published with the permission of the Director of Mines.

References

KHOMENTOVSKIY, V. V., SHENFIL', V. Y., YAKSHIN, M. S., & BUTAKOV, E. P. (1972).—"Opornye razrezy otlozheniy verkhnego dokembriya i nizhnego kembriya sibirskoy platformy" ("Standard sections of Upper Precambrian and Lower Cambrian deposits of the Siberian Platform.") (Publishing House "Nauka": Moscow.)

KOROLYUK, I. K. (1960).—Stromatolity nizhnego kembriya i proterozoya Irkutskogo amfiteatra. (Stromatolites of the Lower Cambrian and Proterozoic of the Irkut Amphitheatre.) *Trudy Inst. Geol. Razrab. Goryuch. Iskop. Akad. Nauk SSSR* **1**, 1-161.

KRYLOV, I. N. (1967).—Rifeyskie i nizhne-kembriyskie stromatolity Tyan'Shanya i Karatau. (Riphean and Lower Cambrian stromatolites of Tien Shan, and Karatau). *Trudy geol. Inst. Leningr.*, **171**, 1-76.

NUZHNOV, S. V. (1960).—Stromatolity pozdnedokembriyskikh i kembriyskikh otlozheniy vostochnykh sklonov Aldanskogo Shchita. (Stromatolites of the late Precambrian and Cambrian deposits of the eastern slopes of the Aldan Shield.) *Dokl. Akad. Nauk SSSR* **132**(6), 1421-1424.

NUZHNOV, S. V. (1967).—Rifeyskie otlozheniya yugo-vostoka sibirskoy platformy. (Riphean deposits of the southeast Siberian platform.) *Inst. Geol. Yakutsk. Filial Sibirsk. Otdel. Akad. Nauk SSSR: Moscow*, 1-160.

PREISS, W. V. (1972).—The systematics of South Australian Precambrian and Cambrian Stromatolites. Part I. *Trans. R. Soc. S. Aust.* **96**, 67-100.

PREISS, W. V. (1973a).—The systematics of South Australian Precambrian and Cambrian stromatolites. Part II. *Trans. R. Soc. S. Aust.* **97**, 91-125.

PREISS, W. V. (1973b).—Palaeoecological interpretations of South Australian Precambrian stromatolites. *J. geol. Soc. Aust.* **19**, 501-532.

SEMIKHATOV, M. A. (1960).—O vertikal'nom raspredelenii stromatolitov v rifeye Turukhanskogo rayona. *Dokl. Akad. Nauk SSSR* **135** (6), 1480-1483.

SEMIKHATOV, M. A. (1962).—Rifey i nizhniy kembriy Yeniseyskogo Kryazha. (The Riphean and Lower Cambrian of the Yenisei Mountains.) *Trudy. geol. Inst. Leningr.* **68**, 1-242.

WALTER, M. R. (1972).—Stromatolites and the biostratigraphy of the Australian Precambrian and Cambrian. *Palaeontology, Spec. Paper* **11**, 1-190, 33 pls.

Fig. 7. *Linella ukka*, Balcanoona Formation, Burr Well, Northern Flinders Ranges. (a)—Longitudinal sections of tuberous columns with pointed projections in outcrop. Marking pen is 10 cm long; (b)—Longitudinal sections of inclined columns at a bioherm margin. Diameter of lens cap is 5 cm; (c)—Cut slab, showing divergently branching columns. The white areas are patches of coarsely crystalline calcite. S478; (d)—Longitudinal thin section (S477); Laminae are largely obliterated by recrystallization; (e)—A cut slab, adjacent to thin section in (d).

Fig. 8. *Linella munyallina*, Wundowie Limestone Member, Northern Flinders Ranges. (a)—Recurved margin of a bioherm, lowest limestone band, Burr Well; (b)—Longitudinal sections of complexly branching columns, Roebuck Bore; (c)—Inclined columns at a bioherm margin. Lowest limestone band, Burr Well; (d)—Outcrop of a small bioherm. Lowest limestone band, Burr Well; (e)—Thin section inclined columns from a bioherm margin. Here the wall is poorly developed. Lowest limestone band, Burr Well. S486; (f)—Thin section of columns with numerous bridges, Munyallina Valley. S294.

Fig. 9. (a–c)—*Linella munyallina*, Wundowie Limestone Member. (a)—Thin section of slightly divergent branching columns. Roebuck Bore. S431; (b)—Thin section of holotype, S495, showing steeply domed laminae in parallel, walled columns. Note sandy lenses in the interspaces; (c)—Thin section of slightly divergent branching columns. West Mount Hut. S555; (d)—*Omachtenia utschurica*, outcrop, uppermost beds of the Tapley Hill Formation, Depot Creek; (e)—As for (d), showing numerous bridges between columns.

Fig. 10. (a–c)—Longitudinal thin sections, *Omachtenia utschurica*. (a)—Illustrating pelletal lamination and coarse intraclasts in interspaces. S166, Depot Creek; (b)—Illustrating details of pelletal microstructure. S399, Depot Creek; (c)—Illustrating broadly banded microstructure; (d, e)—*Tungussia etina;* (d)—Longitudinal outcrop section showing markedly divergent branching, Balcanoona Formation, near Mount Chambers; (e)—Outcrop of irregularly tuberous columns, Etina Formation, Enorama Creek.

Fig. 11. (a) —*Tungussia etina*. Umberatana Group, Flinders Ranges, Longitudinal cut slab showing markedly divergent branching of columns. Wundowie Limestone Member, near Teatree O.S. S441; (b)—Longitudinal thin section of walled columns, Wundowie Limestone Member, near Teatree O.S. S446; (c)—Vertical thin section of variously oriented columns, Balcanoona Formation, near Mount Chambers. Holotype S435; (d) —Wavy, banded lamination seen in thin section, Etina Formation, east of Blinman. S158; (e)—Longitudinal thin section, Balcanoona Formation, near Mount Chambers. S525.

Fig. 12. (a)—Longitudinal thin section, *Tungussia etina*, Wundowie Limestone Member, near Teatree O.S. S286; (b–e)—*Tungussia wilkatanna*, Skillogalee Dolomite, Depot Creek; (b)—Longitudinal thin section illustrating sharp flexure in column. S169; (c)—Outcrop of bushy, divergently branching clump of columns; (d)—Cut slab, S169, illustrating markedly divergent branching; (e)—Thin section, holotype S412, showing markedly divergent branching columns. White areas are silicified.

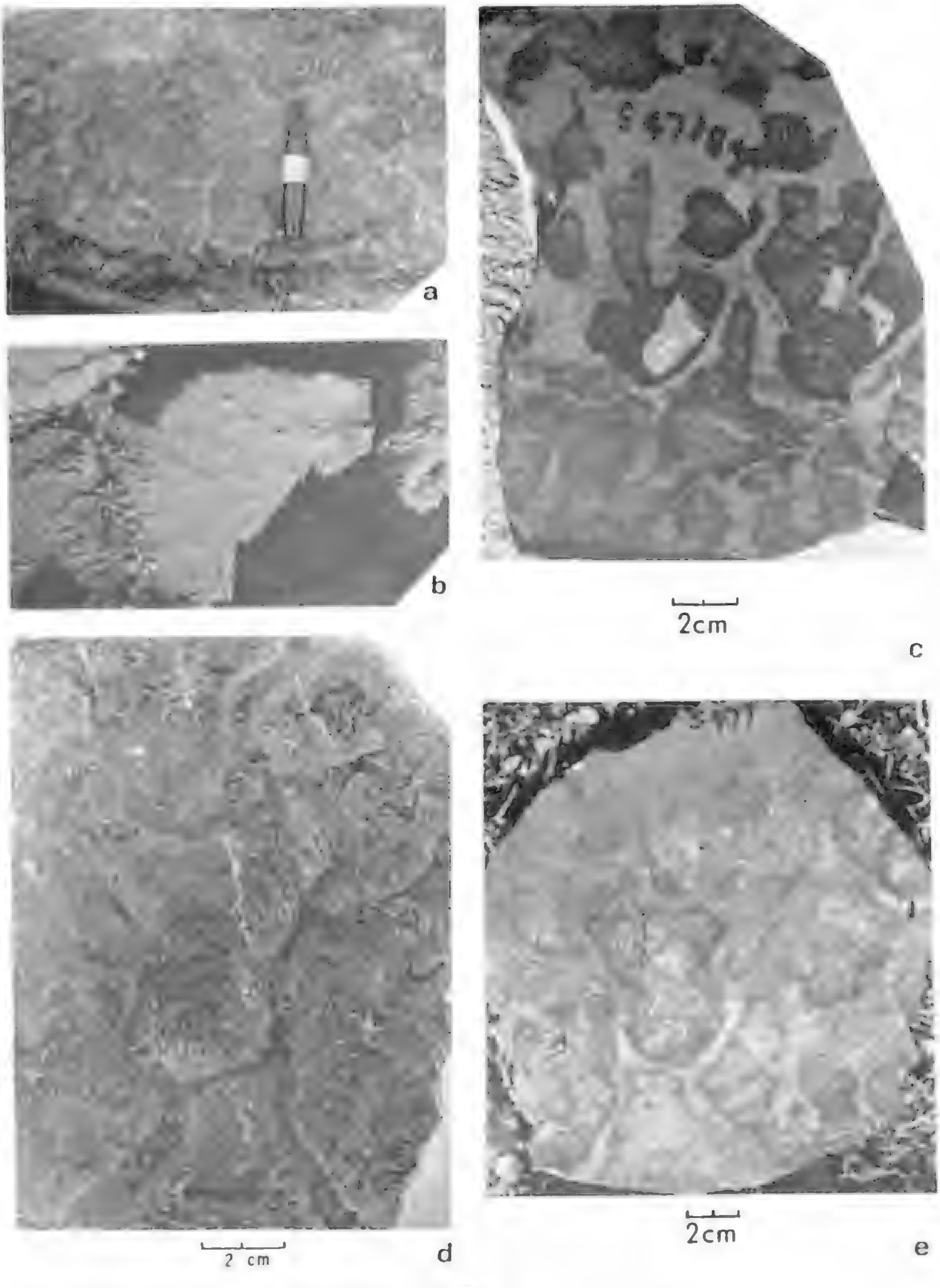

Fig. 7.

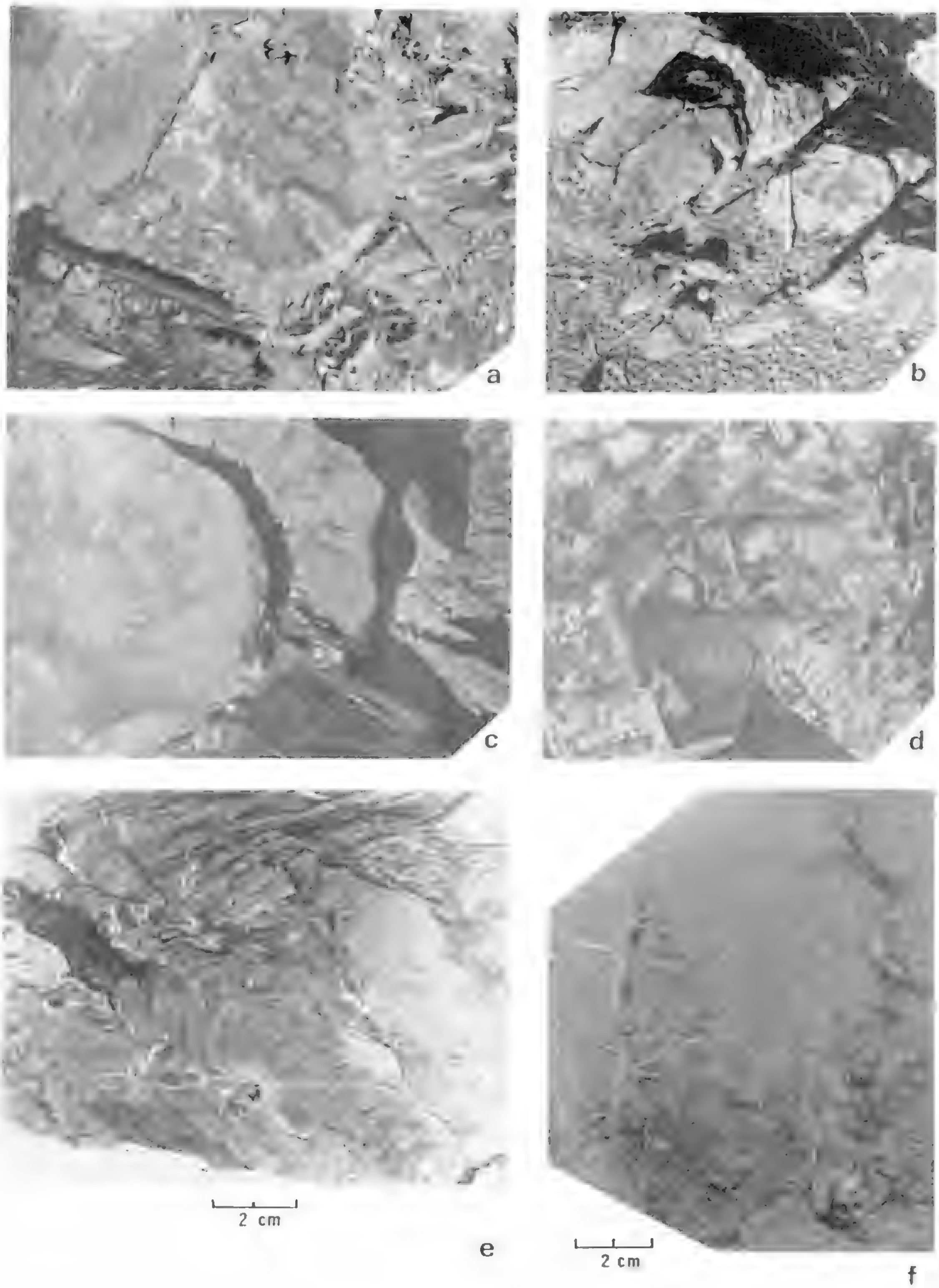

Fig. 8.

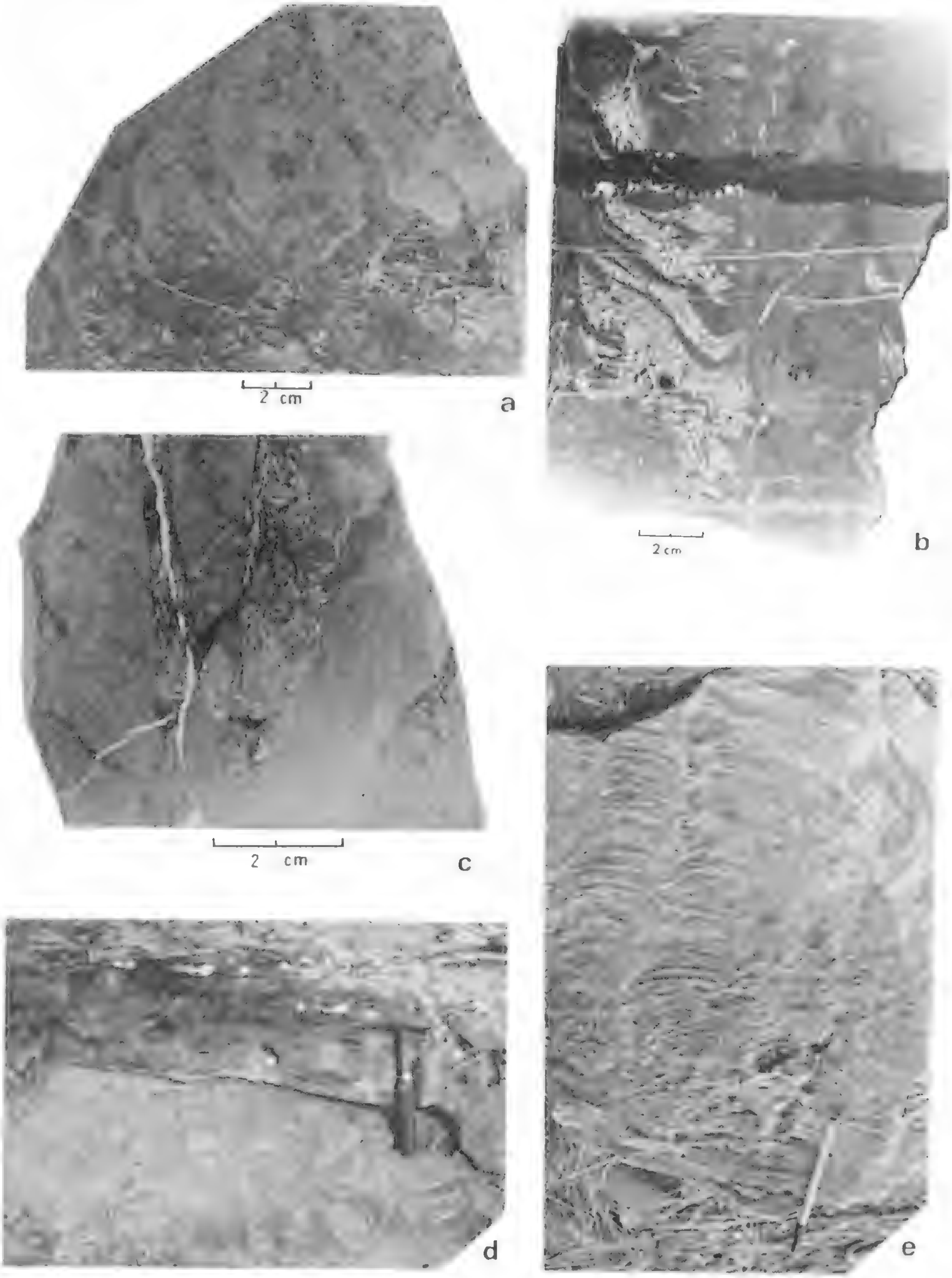

Fig. 9.

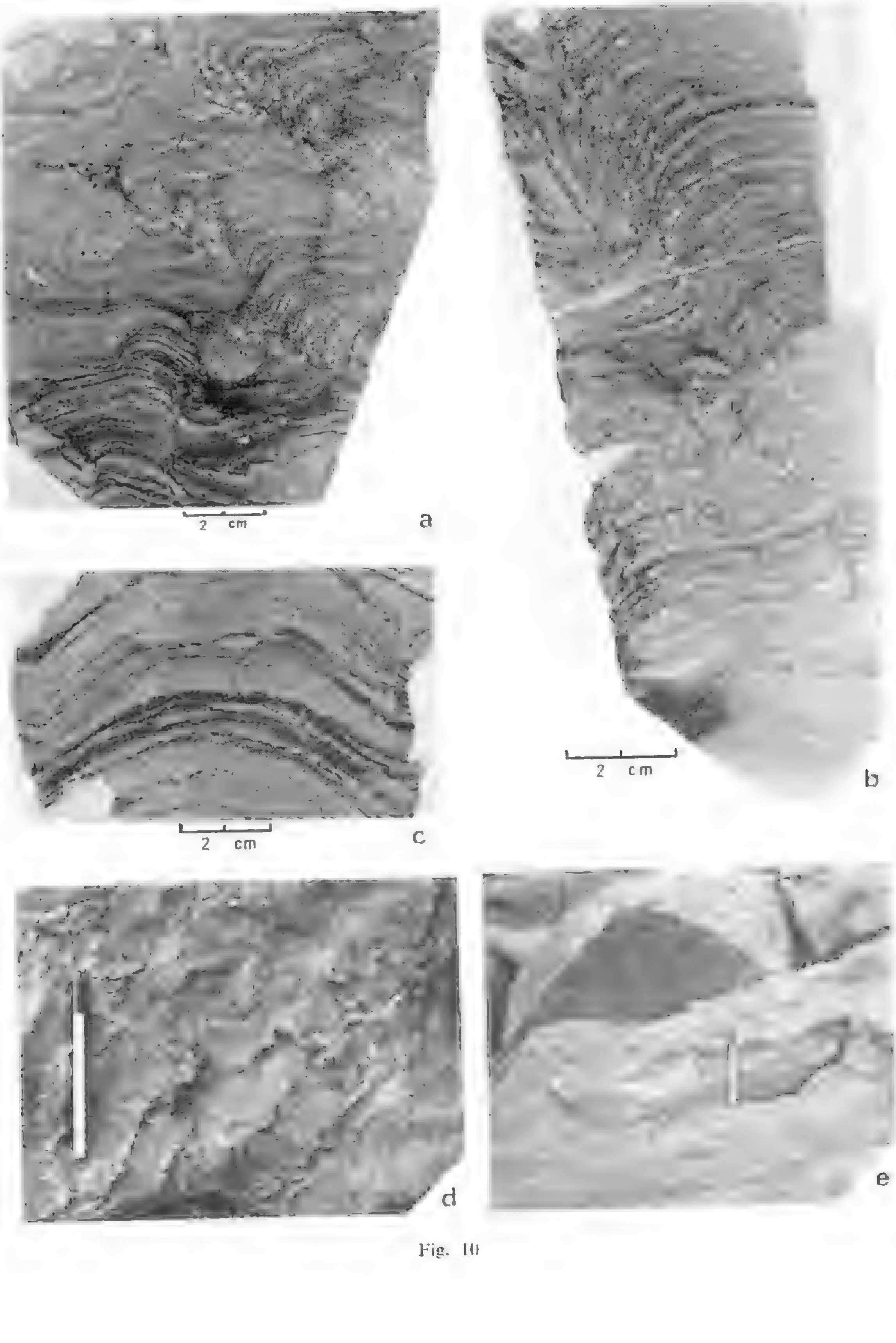

Fig. 10

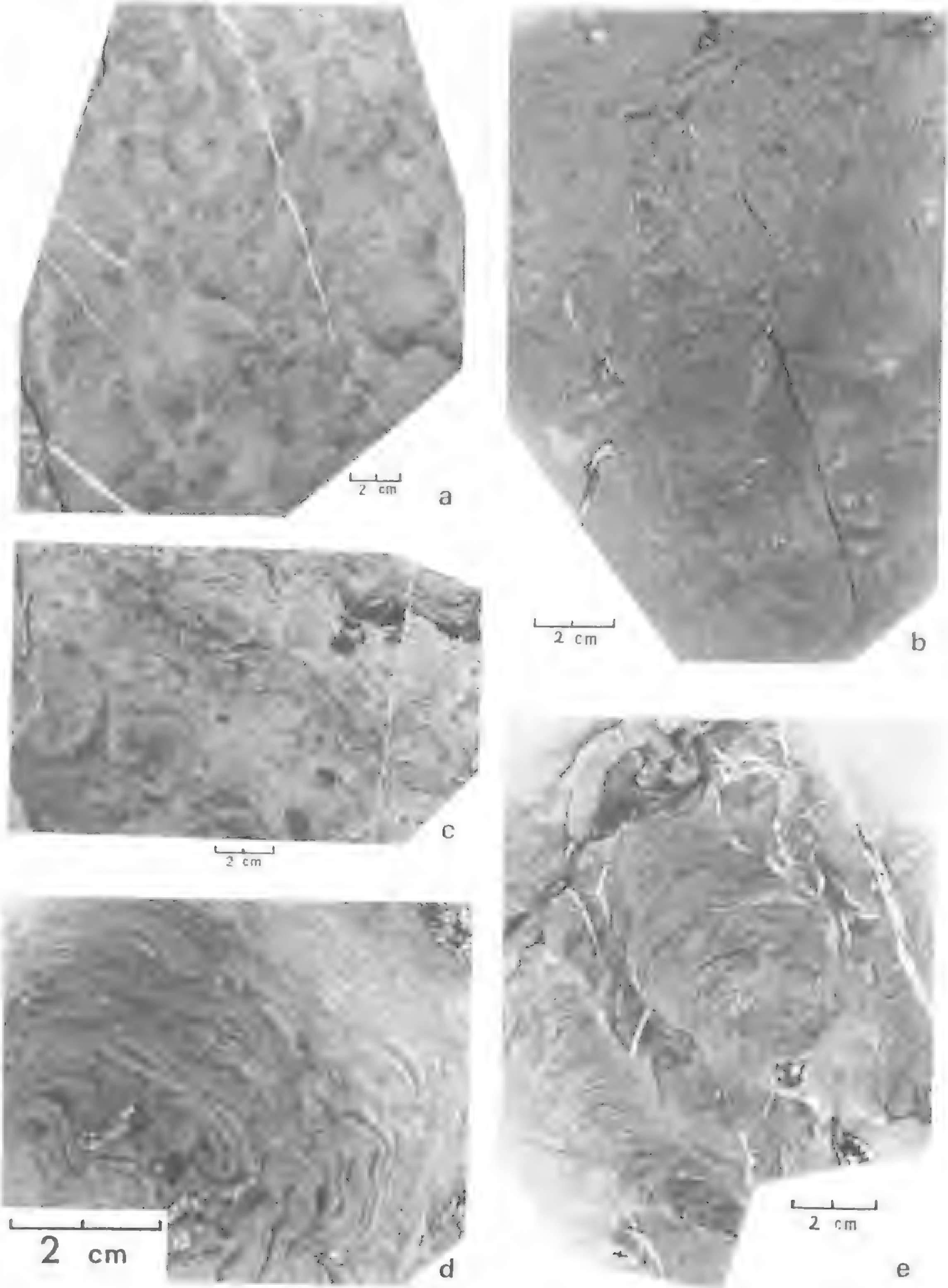

Fig. 11.

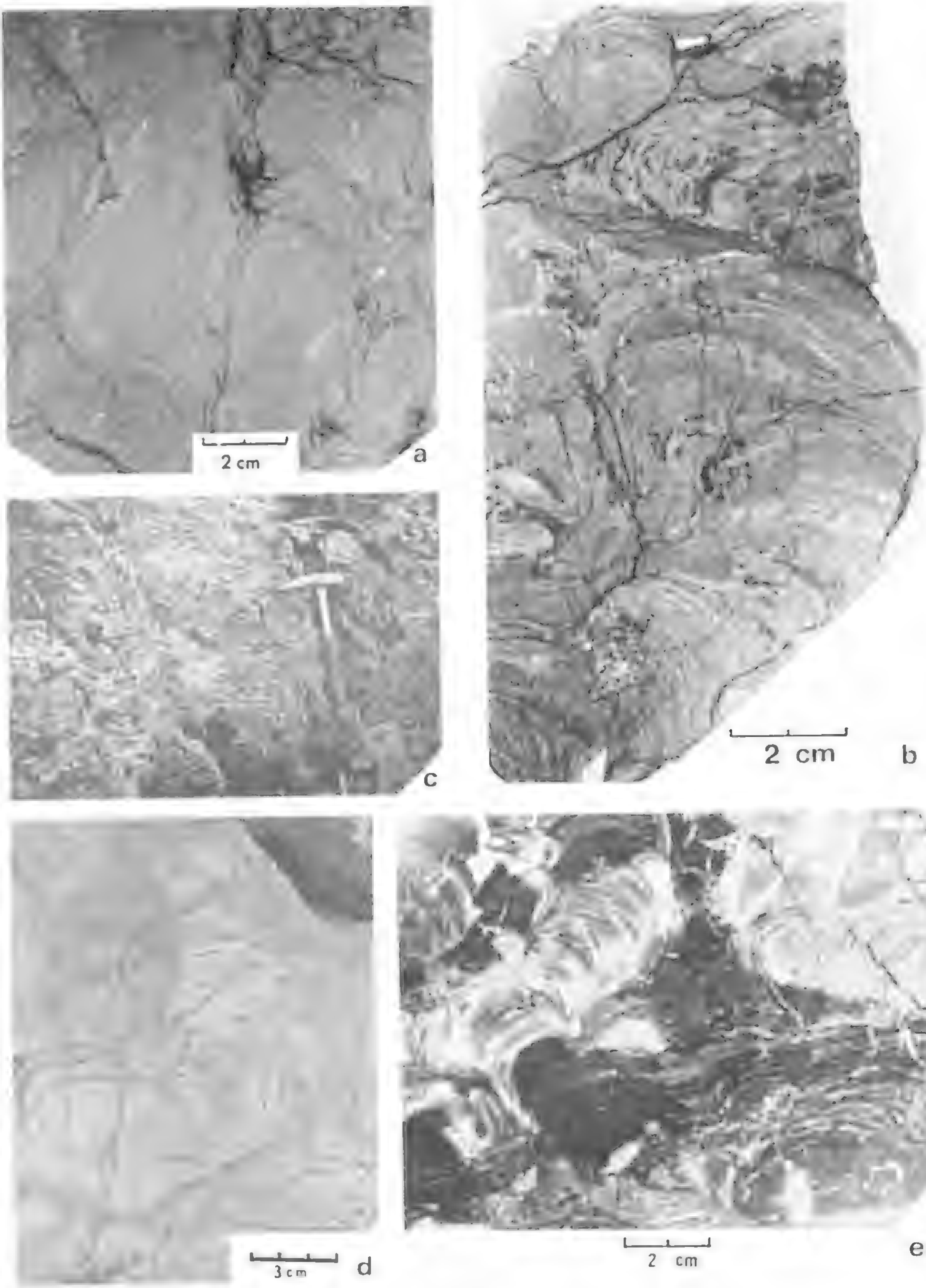

Fig. 12.